

# AT THE ENTERPRISES AND INSTITUTES

UDC 666.198:620.193:666.9.015.427

## STABILITY OF BASALT FIBERS IN A MEDIUM OF HYDRATING CEMENT

F. N. Rabinovich,<sup>1</sup> V. N. Zueva,<sup>1</sup> and L. V. Makeeva<sup>1</sup>Translated from *Steklo i Keramika*, No. 12, pp. 29–32, December, 2001.

The stability of basalt and aluminoborosilicate fibers of different diameters under the effect of an alkaline medium of hydrating cement (concrete) is investigated. Kinetic dependences of CaO absorption by fibers from a saturated solution of  $\text{Ca}(\text{OH})_2$  are determined. General regularities of the variation in the breaking strength of fibers after exposure in the specified solution for 3, 6, or 12 months are specified. The obtained data can be used for analysis and deducing estimated dependences of long-time strength of basalt-fiber composites based on cement matrixes.

The prospects of using basalt fibers as reinforcing components in concrete matrices significantly depend on the stability of fibers to the effect of an alkaline medium generated by hydrating cement.

The present study discusses the results of investigation of basalt fiber and, for reference purposes, of standard glass fiber of aluminoborosilicate composition, which were subjected to the effect of a medium simulating the alkaline phase of portland cement. The chemical compositions and the initial parameters of fibers are indicated in Tables 1 and 2.

The study implied carrying comprehensive testing in two directions:

- determination of the weight share of CaO absorbed by fibers from a saturated  $\text{Ca}(\text{OH})_2$  solution, which is the main alkaline component of the liquid phase of a hydrating cement;
- determination of the breaking strength of fibers after their exposure for a preset time in the specified solution.

Analysis of experimental data was based on the results of rupture tests of 1093 elemental fibers of various diameters (single filaments not less than 5 cm long), including 549 basalt fibers and 544 aluminoborosilicate fibers. Prior to testing, the filaments were divided into groups, each group consisting of 27–36 filaments of the same composition and the same diameter exposed for the same period (3, 6, or 12 months) in a  $\text{Ca}(\text{OH})_2$  saturated solution, or filaments in their initial state (before exposure in the solution). For each group of filaments the mean breaking strength value  $P_m$ , the mean quadratic deviation (standard)  $\sigma_r$ , and the variation coefficient  $v_r = \sigma_r / P_m$  were determined (Table 3).

Testing in a saturated calcium hydroxide solution was carried out at room temperature (about 20°C) and also by means of a quick test involving boiling the fibers in a similar solution. To avoid side effects in testing, fibers were held in a  $\text{Ca}(\text{OH})_2$  solution in polyethylene containers. The solution in its initial state contained 1.19 g/liter calcium hydroxide and 0.9 g/liter (900 mg/liter) CaO.

The weight share of CaO absorbed by fibers was determined using the complexometric method based on the difference between the CaO content in an initial solution (a blank experiment) and the CaO content after holding fibers in the solution for a preset period. After an exposure in  $\text{Ca}(\text{OH})_2$  solution, the fibers before the start of breaking test were thoroughly washed in distilled water and dried between sheets of filter paper. The fiber diameter in the initial state and in subsequent tests was measured in accordance with GOST 6943.2–79, and the tensile strength testing was carried out according to GOST 6943.5–79.

The ultimate tensile stress  $P$  of fibers was found from the expression

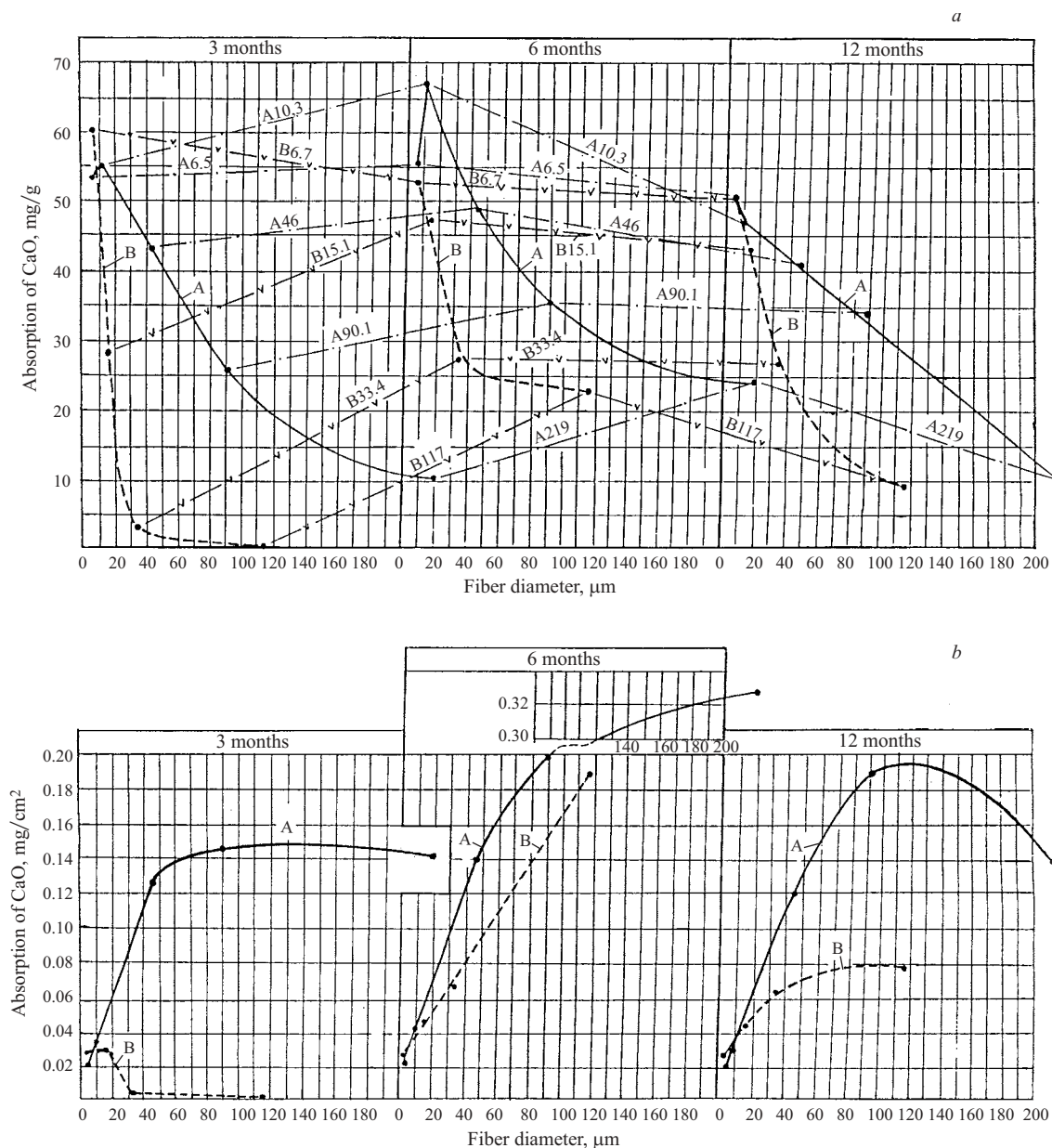
$$P = \frac{4N_r}{\pi d_a^2},$$

where  $N_r$  is the force corresponding to the fiber rupture force and  $d_a$  is the actual fiber diameter.

The weight share of CaO absorbed by fibers from  $\text{Ca}(\text{OH})_2$  saturated solution was found from the difference between the CaO content in the solution before and after boiling.

Figure 1a presents the curves characterizing the kinetics of CaO absorption by a fiber weight unit and Fig. 1b shows absorption by a surface area unit from a saturated solution of

<sup>1</sup> Research Institute of Industrial Buildings, Russia; Stekloplastik Research and Production Association, Russia.



**Fig. 1.** Absorption of CaO from saturated  $\text{Ca(OH)}_2$  solution by a fiber weight unit (a) and fiber surface area unit (b): A and B are aluminoborosilicate and basalt fibers, respectively; digits above curves) variation in the level of CaO absorption by fibers of respective diameters.

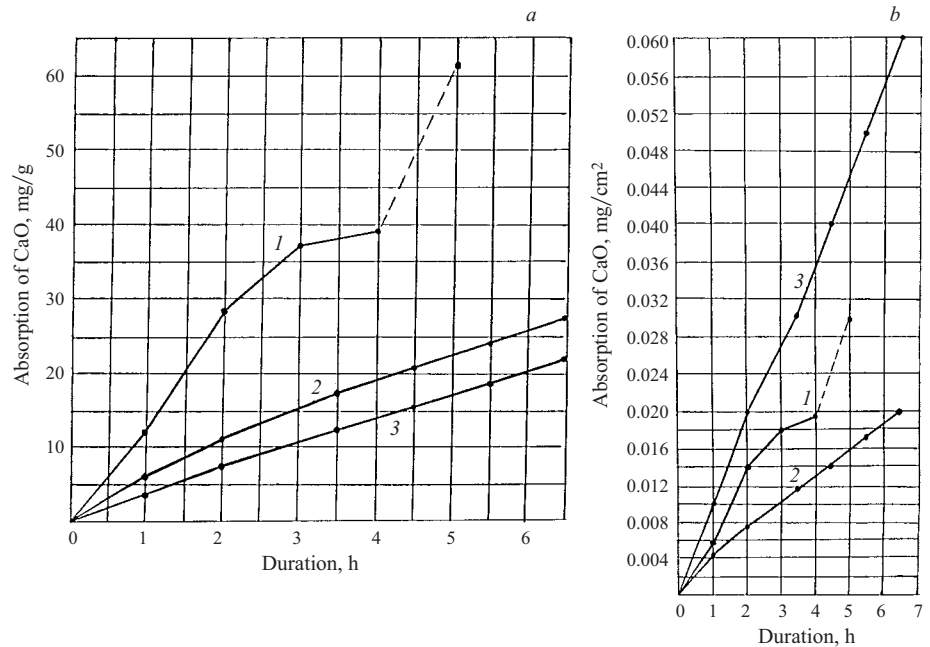
$\text{Ca(OH)}_2$ . The following can be noted: all considered fibers in time absorb CaO from an alkaline solution: the most intense absorption of CaO happens in the first 3–6 months, and the degree of CaO absorption increases as the fiber di-

ameter decreases (as the surface area of contact with the alkaline medium increases).

The levels of CaO absorption by basalt fibers of 6.7  $\mu\text{m}$  diameter and aluminoborosilicate fibers of 6.5  $\mu\text{m}$  do not

**TABLE 1**

Fiber	Mass content, %										calcination loss
	$\text{SiO}_2$	CaO	$\text{B}_2\text{O}_3$	$\text{Al}_2\text{O}_3$	FeO	$\text{Fe}_2\text{O}_3$	MgO	$\text{TiO}_2$	$\text{Na}_2\text{O} + \text{K}_2\text{O}$	$\text{P}_2\text{O}_5$	
Aluminoborosilicate	54.50	16.00	10.01	14.50	—	—	4.00	—	0.20	—	0.28
Basalt	51.40	10.26	—	14.83	8.47	1.73	5.92	0.84	2.42 + 1.20	0.32	1.68



**Fig. 2.** Absorption of CaO from saturated  $\text{Ca(OH)}_2$  solution by a fiber weight unit (a) and fiber surface area unit (b) in boiling: 1) aluminoborosilicate fibers of diameter 7.9  $\mu\text{m}$ ; 2 and 3) basalt fibers of respective diameters 10 and 38  $\mu\text{m}$ ; dashed lines) the level of CaO during the last (fifth) hour of boiling, before which there was an interruption of 17 h caused by technical reasons.

significantly differ during the entire observation period. As the fiber diameter increases, the situation changes. For instance, the level of CaO absorption in basalt fibers of diameters 15.1 and 33.4  $\mu\text{m}$  is lower than in aluminoborosilicate fibers of diameters 46.0 and 90.1  $\mu\text{m}$ . At the same time, the level of CaO absorption by aluminoborosilicate fibers also decreases, as their diameter increases.

The curves of CaO absorption from  $\text{Ca(OH)}_2$  saturated solution in boiling fibers (Fig. 2a) on the whole are similar. It should be noted that the boiling test was stopped only after the increment in CaO absorption by fibers had ceased.

It was earlier [1] demonstrated that CaO absorption by a fiber surface area unit from  $\text{Ca(OH)}_2$  saturated solution grows with increasing diameter. It was assumed that this circumstance is related to the possible variation in density in the surface layer of fibers (as the structure of the surface layer loosens). As a result of testing of fibers, it was found as well that as the fiber diameter increases, the level of CaO absorption by a surface area unit becomes higher (Fig. 1). However, CaO absorption curves on the whole damp with increasing fiber diameter.

The considered regularities were observed as well in boiling of fibers. Aluminoborosilicate fibers of 7.9  $\mu\text{m}$  diameter absorbed significantly more CaO per weight unit than

basalt fibers of diameters 10 and 38  $\mu\text{m}$  (Fig. 2a). The CaO absorption per surface area unit of basalt fibers was the highest in 38- $\mu\text{m}$ -diameter fiber, and the lowest in fibers of diameter 10  $\mu\text{m}$ . Aluminoborosilicate fibers 7.9  $\mu\text{m}$  in diameter in this case take an intermediate position (Fig. 2b).

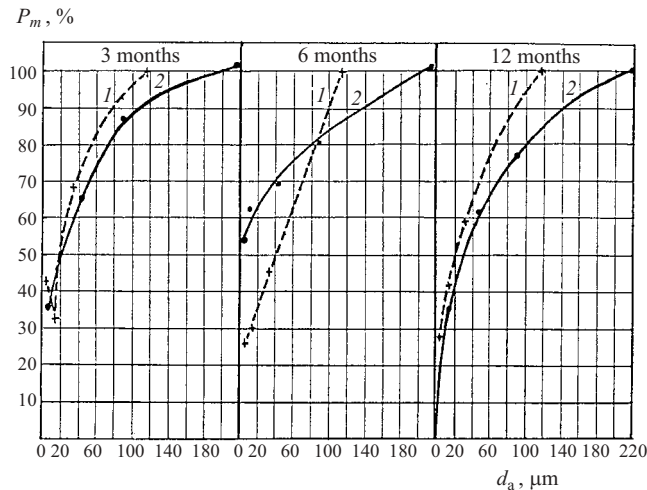
**TABLE 2**

Fiber diameter, $\mu\text{m}$	Variation coefficient, %	Specific surface area, $\text{cm}^2/\text{g}$	Initial breaking strength, MPa	Variation coefficient, %	Number of fibers tested
<i>Aluminoborosilicate fiber</i>					
6.5	9.9	2461	2298	12.6	32
10.3	7.7	1553	2416	9.9	31
46.0	6.1	348	808	19.1	32
90.1	10.9	177	630	25.8	28
219.0	16.5	73	220	38.4	30
<i>Basalt fiber</i>					
6.7	3.3	2132	2014	15.6	27
15.1	4.9	946	2329	14.9	36
33.4	9.8	427	1785	25.1	34
117.0	13.8	122	371	37.1	32

\*  $S = \frac{4}{d_a \gamma}$ , where  $\gamma$  is the fiber density: 2.5  $\text{g}/\text{cm}^3$  for aluminoborosilicate fiber and 2.8  $\text{g}/\text{cm}^3$  for basalt fiber.

**TABLE 3**

Exposure duration, months	Variation coefficient of fiber strength after exposure in a saturated solution of $\text{Ca(OH)}_2$								
	aluminoborosilicate, of diameter, $\mu\text{m}$					basalt, of diameter, $\mu\text{m}$			
	6.5	10.3	46.0	90.1	219.0	6.7	15.1	33.4	117.0
3	22.0	21.7	24.0	35.1	49.2	16.3	23.7	25.4	39.0
6	22.2	21.3	29.4	29.1	53.6	20.2	18.8	23.3	38.3
12	—	19.1	24.9	26.0	48.4	15.7	22.6	41.5	42.6



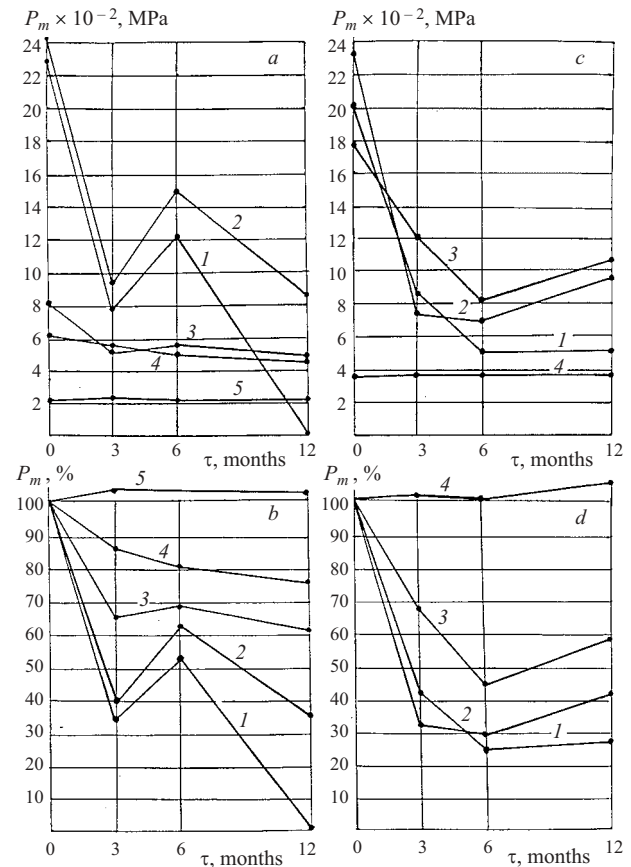
**Fig. 3.** Variation in the tensile strength of fibers  $P_m$  after exposure in a saturated solution of  $\text{Ca(OH)}_2$ : 1 and 2) basalt and aluminoborosilicate fibers, respectively.

The data characterizing the unit value of CaO absorption by fiber surface area are of great importance, since they correlate with the thickness of the fiber layer destroyed on the surface by the alkaline medium. These data can be used to analyze the parameters of the long-time strength of fiber.

Figures 3 and 4 show variations in the average breaking strength of fiber exposed in a saturated solution of  $\text{Ca(OH)}_2$  compared to its initial strength. The strength variation coefficients are indicated in Table 3.

All the considered fibers except for fibers of sufficiently large diameters exhibit a decrease in strength after exposure in a saturated solution of  $\text{Ca(OH)}_2$ , i.e., a medium simulating the alkaline phase of solidifying portland cement. The smaller a fiber diameter, the more perceptible is its decrease in strength. This process is the most intense in the first 3–6 months. The strength decrease on the whole is a damping process. The greatest loss of strength is observed in aluminoborosilicate fibers.

It is also advisable to note certain fluctuations in strength typical of the considered fibers. Thus, a decrease in the strength of aluminoborosilicate fibers of 6.5  $\mu\text{m}$  diameter after exposure for 3 months in  $\text{Ca(OH)}_2$  saturated solution constituted over 60% of the initial strength, and after 12 months, these fibers completely lost their strength. Basalt fibers of diameter 6.5  $\mu\text{m}$  after a 3-month exposure in similar conditions retained over 40% strength, and preserved 28% strength after a 12-month exposure.



**Fig. 4.** The effect of exposure duration  $\tau$  in a saturated solution on the tensile strength of fibers  $P_m$ : a, b) are aluminoborosilicate fibers of diameter 6.5 (1), 10.3 (2), 46.0 (3), 90.1 (4), and 219.0 (5)  $\mu\text{m}$ ; c, d) are basalt fibers of diameter 6.7 (1), 15.1 (2), 33.4 (3), and 117.0 (4)  $\mu\text{m}$ .

As the fiber diameter increases, the level of strength loss decreases, which is most markedly manifested in basalt fibers. Aluminoborosilicate fibers of diameter 219  $\mu\text{m}$  and basalt fibers of diameter 117  $\mu\text{m}$  retained their strength after exposure in saturated  $\text{Ca(OH)}_2$  solution for one year.

The obtained data can be taken into account in analysis and deducing estimated dependences of the long-time strength of basalt-fiber composites based on cement matrixes.

## REFERENCES

1. F. N. Rabinovich, "A study of durability of fiberglass cement," in: *Building Structures and Materials, Issues 3–4* [in Russian], VNIINTPI, Moscow (1992), pp. 27–33.